VOLUME 81 SEPARATE No. 616

PROCEEDINGS

AMERICAN SOCIETY
OF
CIVIL ENGINEERS

FEBRUARY, 1955

BEACH REHABILITATION BY FILL AND NOURISHMENT

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WATERWAYS DIVISION

{Discussions open until June 1, 1955}

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Printed in the United States of America

Headquarters of the Society
33 W. 39th St.
New York 18, N. Y.

PRICE $0.50 PER COPY

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This paper was published at 1745 S. State Street, Ann Arbor, Mich., by the American Society of Civil Engineers. Editorial and General Offices are at 33 West Thirty-ninth Street, New York 18, N. Y.

BEACH REHABILITATION BY FILL AND NOURISHMENT

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SYNOPSIS

Shore stability and alignment have been greatly influenced by the progressive development of seaside resorts and the construction of navigable inlets. Over the past several years various methods of artificial nourishment, by use of beach fills, have been applied and their success has been varied. The basic methods of utilizing beach fill to maintain artificial nourishment are: stockpile, which is the placing of the fill at one point and allowing it to function as a feeder beach; direct placement, which involves placing the material along the beach and creating an adequate beach width for immediate protection, which creates a littoral supply to the down drift area and continuous nourishment, where a fixed or semi-fixed plant is positioned on the updrift side of a jettied inlet and the plant intercepts and by-passes the littoral drift to the downdrift side of the inlet. It is the purpose of this paper to review several cases where these methods of artificial nourishment have been employed and show the experience record.

INTRODUCTION

The mechanics of transporting sediment by water is not completely understood, however, it is known that for a movable bed to be in a state of equilibrium, there must be a balance of energy distribution in terms of bed aggradation and degradation. For this reason, coastal beaches can reach stability or equilibrium and maintain this condition only when there is a sufficient supply of littoral drift for the natural forces involved. Insufficient littoral supply will tend to create erosion of the beach and an over abundant supply will cause accretion. In terms of geological time, very little of any coastline is in a stable state, but in terms of decades there are stable reaches of shore line. It is only natural that economical development of a coastal region will point towards these stable zones.

Prior to the extensive economic development of the United States, natural forces built and molded the beaches from an abundant supply of material derived from stream sediments carried to the shore during periods of flood and from eroding headlands. The discovery of the beaches as a playground and their ensuing development, have greatly influenced a gradual change on these areas as far as beach stability is concerned. Also, shore stability and alignment have greatly been influenced by the construction of navigable inlets and inlets for the purpose of alleviating stagnant conditions in bays and lagoons.

The first seaside resorts were supported mainly by local inhabitants but as transportation improved and people had more and more free time for

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recreation, the beach development grew. These centers of recreation however, did not line our shores but were spotted here and there, usually near the large centers of population where economic justification would permit the construction of public transportation systems. The primary purpose in building a resort area is to cater to the public who prefer to live on the beach when they visit it. The ensuing growth of hotels and other facilities at the beach soon established a line beyond which the shore could not be allowed to erode. In view of this condition coastal engineers employed structures such as seawalls to prevent the erosion of the fast land, and groins to impound the littoral materials. The structures were reasonably successful in holding and building the beaches during the period when the up-drift shoreline was undeveloped and its erosion furnished material to the littoral stream. As the intervening beach area was developed and protected from erosion, harbor entrances constructed and improved with jetties and flood control dams built on the rivers, the quantity of material supplied to the littoral zone became less and less. This situation exists at a large number of beaches today.

The problem that now confronts the coastal engineer is: what is the best and most economical method of protecting, and rehabilitating a beach that receives an inadequate supply of littoral material? The problem appears to be simple in that all that is required is to reestablish the supply of material. However the method of placing the beach fill, so that the fill will function to supply at the replenishment rate, is an extremely important factor.

There has been a lack of general understanding by the public, and to some extent in the engineering profession, as to the intended functioning of beach fills. There are several purposes for which such fills are designed, one of which is to afford nourishment to shores downdrift of the filled area. This type of fill often includes a proportion of its width which is intended to be permanent and the remaining seaward proportion of the fill dedicated as a stockpile. The stockpile is designed to erode at the natural rate of littoral drift, and by eroding, provide nourishment to maintain the downdrift shore. The establishment, and periodic replenishment of such a stockpile beach is called artificial nourishment.

When artificial nourishment is applied as a remedy for a long reach of starved and eroded shore, it is often necessary to first rehabilitate the shore by filling to provide the desired protective beach without delay. Fill for this purpose is termed, direct placement, and it is normally designed to the dimensions which it is desired to maintain. When such a fill is made, it will remain effective only if it is artifically nourished. The two methods of artificial nourishment are the stockpile method described above, and the more or less continuous feeding which results from a fixed or semi-fixed by-passing installation. Artificial nourishment is thus a sand-moving operation, the method depending upon the required rate and the source of material. Because it is suitable for maintaining long reaches of shore by a single operation it is often more economic than defensive works, such as seawalls or groins. Its greatest value over defensive methods lies in the fact that it prevents rather than causes the spreading of an erosion problem.

Over the past several years these methods of artificial nourishment have been applied and their success has been varied. It is the purpose of this paper to review several cases where these methods of nourishment have been employed and show the experience record. Some of the protective measures to the cases presented herein have not been in effect sufficiently long to reflect conclusive results however, the problem leading to the choice of protection is believed to be of great significance in these cases. The references cited in

each beach problem presents a comprehensive description of the area and only the most pertinent information is included herein.

DIRECT PLACEMENT AT WEST HAVEN, CONNECTICUT

The West Haven, Connecticut shore line, refer to figure 1, comprises the shores of Long Island Sound near the entrance to New Haven Harbor which is about 50 miles east of New York City. In general all of the shore line within Long Island Sound is of interest in view of the reduced wave action, as compared to the open ocean shore line, yet there exist serious problems of beach restoration and stabilization. The West Haven area has been selected to depict a somewhat typical problem along these shores and the measures taken to improve the shore line condition.

The headlands and lowlands of the West Haven area are comprised of unconsolidated glacial drift materials which erode easily by wave action. This source of supply of beach building material has gradually been reduced with intensive development of the shore for residential and resort purposes. Protective structures have been erected in developed areas to limit the recession of the shore line and this has transferred the erosion to undeveloped areas. As pointed out in a Beach Erosion Control Study[3] of this area, "The problem is to stabilize and improve the shore line so that existing and future development on the shore front may benefit from restored beach conditions and also to prevent future damages and losses which will otherwise inevitably result from the present deterioration."

The present quantity of littoral drift in the West Haven area, and in general along the coast of Connecticut, is small. There appear to be many nodal points as created by rocky headlands, where the direction of littoral drifts divides. In the West Haven area between Bradley Point and Sandy Point, the predominate direction of drift is to the east. Long Island acts as a natural breakwater which shields practically all of the shore of Connecticut, therefore the wave action in this area is greatly reduced as compared to the shores completely exposed to the open ocean. The moderately flat nearshore and offshore slopes combined with maximum fetch distances of 20 to 30 miles does not permit severe wave action to reach the actual backshore, and it is the relatively small waves that contribute to the gradual erosion and deterioration of the shore line.

This condition of a short fetch distance and hydrography tends to produce a wave climate of short period waves which in general create offshore deposition along with the small quantity of material movement in the littoral stream. In this area the offshore deposits are within practicable distance for hydraulic dredging and pumping to the foreshore. The Beach Erosion Control Study, previously mentioned, covers the shore line from New Haven Harbor to Housatonic River, Conn.; this study indicates that the most economical and practical approach to restoration and stabilization of this area is by direct placement of sand on the beaches coupled with groin construction to prevent along shore erosion of restored beaches.

From July 1948 to January 1949 over 1 million cubic yards of maintenance dredged sand was pumped from the New Haven Harbor Navigation channel to the shore south of Sandy Point. Prior to placement of this spoil sand, this

3. U. S. Army, Corps of Engineers, Beach Erosion Control Study, March 1952, Area 3- New Haven Harbor to Housatonic River, Connecticut; House Document #203, 83rd Congress, 1st Session.

reach of shore was in a critical condition in terms of endangering works located immediately on the backshores. The direct placement of sand on the beach in this area provided protection to the backshore, in addition to providing an extensive recreational area. Comparison of surveys made in October 1949 and April 1950, covering the area from Sandy Point to Bradley Point, indicates that the mean high water line has not changed appreciably. A comparison of plan areas between the mean high and low water lines for these two surveys indicates a reduction of about 25 per cent; this rather rapid reduction of foreshore zone indicates that a readjustment of the foreshore slope is taking place and until this readjustment is completed, overall evaluation of the sand placement in this area would be difficult to establish.

The significant feature of this problem is that the construction of shore structures such as groins to retain the littoral drift, must be coupled with artificial fill. In general, groins alone in the area are ineffective due to small rates of drift and they deprive the downdrift zones of the limited littoral supply which results in excessive erosion of the downdrift shore line. When all factors are considered, it becomes more evident why the most economical and practical approach to restoration and stablization of this area is by means of direct placement of sand and groin construction.

OFFSHORE DEPOSITION AND DIRECT PLACEMENT AT ATLANTIC CITY, NEW JERSEY

Atlantic City lies on the Coast of New Jersey about 45 miles northeast of Cape May which is the southern tip of the State at the entrance to Delaware Bay. It comprises nearly one-half of the barrier beach known as Absceon Island. Absecon Inlet is the northeastern boundary of the City and Island.

Atlantic City has developed rapidly since the turn of the century because of its location near extensively developed and densely populated urban areas. Philadelphia and New York City lie about 60 and 125 miles respectively from this resort area.

The broad sand beach for which Atlantic City is famous was supplied with material transported southward along Absecon Island. Dredging volumes removed from Absecon channel between 1935 and 1946 indicate that about 400,000 cu. yds. of material reach the southern end of the Island annually. It cannot be stated whether the serious erosion that has taken place on the ocean beach at Atlantic City is the result of a diminished rate of supply of sand to the beach or to a greater rate of loss of sand from the beach due to an increase in power of the eroding forces. It is believed that both factors contribute to the erosion but the prominence of one over the other would be extremely difficult to determine in this case.

Although the beach remained relatively stable prior to 1940, it was decided that augmented nourishment to the beach would be beneficial. The nourishment supplied was derived from hopper dredging operations in Absecon Inlet. During the period April 1935 to September 1943, approximately 3,554,000 cu. yds. of sand were deposited off the beach in 15 to 20 feet of water, see figure 2. This operation was followed very closely to determine if any perceptible quantity of the dumped material was moved to the beach. The findings were negative and reports indicate that serious erosion of the beach for a distance of 6,000 feet south of the inlet became evident around 1940.

Realizing that a positive method of construction and rehabilitation of the beach would be required if the expensive real estate lining the shore was to be preserved, the City of Atlantic City entered into an agreement with the Corps of Engineers, U. S. Army, to make a beach erosion control study.

As a result of the study[4] the following plan of improvement was recommended for the ocean beach section.

a. Maintain the channel on an east-west alignment away from the ocean beach.

b. Construct 5 timber groins and extend one stone groin starting with the one farthest west and work eastward.

c. Replenish and maintain the beach with artificial nourishment as required.

The State of New Jersey and City of Atlantic City started the rehabilitation work in 1948. They constructed a stone jetty at Oriental Avenue to divert the inlet channel eastward away from the beach and placed approximately 700,000 cu. yds. of sand on the beach from the jetty to a point about 6,000 feet southward. The sand used for nourishment was pumped from the southern tip of Absecon Island.

Immediately upon the completion of the fill, the beach started to erode at a rate greater than that normally encountered during the adjustment of the beach profile. As a matter of fact the erosion progressed at such a rapid rate that the City of Atlantic City constructed the five timber groins recommended in the plan of improvement. The groins immediately started to function as planned. They reduced the rate of loss of material to the downdrift beaches and the eroding beach started to rebuild.

At the present time the beach, as far south as St. Charles place has accreted in width equal to or greater than that which it had immediately after the direct placement of sand was made. City officials indicate that the rebuilding process is gradually moving southward and evidences of improvement are apparent at the North Carolina Avenue groin.

The information given above indicates that the beach would have built up through the use of groins without artificial nourishment. This fact was never questioned. The nourishment was provided to restore the beach to its former dimensions as rapidly as possible to protect the beach front property from unusual storms.

This type of rehabilitation will often be needed and the delay in constructing groins to observe the behavior of the new fill is sound economically in that in some instances groins would not be required.

DIRECT PLACEMENT AT VIRGINIA BEACH, VIRGINIA

The city of Virginia Beach, refer to figure 3, is located 3.5 miles south of Cape Henry, Virginia which is the southerly point of the entrance to Chesapeake Bay. The shore frontage of the city is about 3.3 miles in length. The shore line of this area has been developed chiefly for resort and recreational purposes.

This beach area started as a resort around 1890. It has steadily gained in popularity, and at the present time a conservative estimate of gross annual business is about 12 million dollars. Prior to the shore frontage development, sand dunes of considerable size existed and erosion of these dunes supplied material to create and maintain the beach. With the erection of buildings and protective structures, these fore dunes were removed, which reduced if not virtually cut off the supply of sand which normally fed the beach or foreshore

4. U. S. Army, Corps of Engineers, Beach Erosion Control Study, 30 January 1950, Atlantic City, New Jersey; House Document #538, 81st Congress, 2nd Session.

zone. In 1927, the town of Virginia Beach constructed 1.93 miles of concrete seawall and promenade to protect the most extensively developed shore frontage. It is of interest to note that the initial cost was $250,000.00 and maintenance and repair expenditures on this structure as of 1 April 1949, were $326,534. In 1950 the high water line was, in general, at the toe of the seawall and endangered much of the shore line resort facilities.

A Beach Erosion Control report[5] on the cooperative study of Virginia Beach was submitted in late 1951. The purpose of this investigation was to determine the most suitable method of restoring and preserving an adequate beach for protecting the seawall and upland, and for recreational use.

Statistical wind and ocean swell data which could be applied to Virginia Beach indicate a predominate direction from the Northeast and East, however, offshore bottom hydrography and tidal currents from the entrance to Chesapeake Bay influence the wave pattern to an extent that littoral characteristics cannot be defined. Seasonal reversals in direction of drift are apparent, with an appreciable volume being transported in either direction. Based on 46 years of record, the high water line has shown continual recession and represents a net loss of 36,000 cubic yards per year in the problem area.

After considering all the evidence involved in the problem area, the recommended plan, as presented in the previously referenced report, was to widen the existing beach by artificial placement of fill sufficiently to provide protection of the seawall and upland, and maintain it by replenishment of losses at suitable intervals to insure continuous protection. The plan included deferred groin construction for protection works with the provision that their construction be based on data derived from the results of the artificial replenishment and the effect of lower annual costs.

By the summer of 1953, 1,400,000 cubic yards of sand had been hydraulically placed on the beach along the city's shore frontage. The material was derived from dredging Rudee Inlet and Lake which is located at the southerly limit of the study area. To date, the placed fill has protected the property along the shore line and the annual losses of material from the beach has been in order with the expected maintenance program. There has been insufficient time in terms of the initial placement and subsequent maintenance, to evaluate the deferred groin construction plan.

STOCKPILING AT PALM BEACH, FLORIDA AND CONTINUOUS NOURISHMENT AT SOUTH LAKE WORTH INLET, FLORIDA

Prior to rehabilitation measures, the shore frontage of the Town of Palm Beach and the shores south of South Lake Worth Inlet were experiencing recession which was due, mainly, to the reduction of a natural supply of littoral drift after the construction of inlets with entrance jetties.

As indicated on figure 4, Palm Beach is located on the east coast of Florida, about 70 miles north of Miami. The town has been built on a barrier beach which separates Lake Worth from the Atlantic Ocean. The barrier varies in width from 250 feet to about 3,600 feet and extends about 16 miles between Lake Worth Inlet and South Lake Worth Inlet, these inlets being the only waterways between Lake Worth and the ocean. The major development of the Palm Beach shore line is situated in the reaches to the south of Lake

5. U. S. Army, Corps of Engineers, Beach Erosion Control Study, 22 August 1952, Virginia Beach, Virginia; House Document #186, 83rd Congress, 1st Session.

Worth Inlet. This inlet was dredged through the barrier and two entrance jetties constructed between 1918 and 1925. The north jetty is approximately 2,000 feet in length and the south jetty is about 1,900 feet, as measured from the 1920 shore line. The predominate direction of littoral drift in this area is from north to south and estimates of the annual impounding rate of the north jetty, after construction of this jetty, ranged from 150,000 to 225,000 cubic yards. Since the construction of the inlet and jetties, the normal supply of material to the reaches south of the inlet has been greatly reduced. Between 1926 and 1946 approximately $1,548,000 had been expended for construction and maintenance of bulkheads and groins towards shore protection. Groins were virtually ineffective in retaining material inasmuch as the supply was limited. In 1944 hydraulically dredged material, derived from the turning basin in Lake Worth, was deposited on the beach about 1,500 feet south of the south jetty of Lake Worth Inlet. It was estimated that 282,000 cubic yards of sand was deposited on the beach in the form of a stockpile. It was reported that this material was transported up and downcoast and became impounded between the groin fields. The effect of the 1944 artificial placement of sand was beneficial for one-fourth mile north and 1-1/2 miles south of the stockpile.

It became apparent that this relatively small quantity of artificial nourishment was merely an aid until a more comprehensive beach rehabilitation program could be undertaken. Accordingly, a Beach Erosion Control Study[6] was completed in 1947. This report concluded that the most suitable minimum plan of improvement for the rehabilitation and protection of Palm Beach was the placement of 1 million cubic yards of suitable material, dredged from Lake Worth, in five stockpiles on the beach, thereafter, periodic subsequent replenishment and maintenance of existing seawalls, bulkheads, and repairable groins. The stockpiles were to be placed at critical portions of the beach. It was estimated that this initial volume of placement would be depleted in about 5 years. This plan of rehabilitation was undertaken and the stockpiling completed in 1948. Approximately 2 million cubic yards of material was stockpiled instead of the 1 million recommended. The total cost of this operation being about $400,000. This artificial nourishment has offered adequate protection to the 13 miles of ocean front property in Palm Beach since 1948.

In the past year, Town Officials have been active in following the recommended plan of shore line maintenance. The officials have also been considering the most feasible plan to mechanically transport the sand impounded by the north jetty of Lake Worth Inlet to the shores south thereof.

South Lake Worth Inlet which is located about 16 miles south of Lake Worth Inlet was dredged through the barrier beach in 1927 in order to create a circulation of water through Lake Worth. The north and south entrance jetties protecting this channel are respectively, 310 and 320 feet in length. After construction of the inlet and jetties there was an immediate reduction of littoral material supply to the shores south of the south jetty. The predominate direction of littoral drift in this area is from north to south. Between 1932 and 1937 property owners in these reaches constructed protective works in the form of seawalls and groins to check the erosion, however the supply of drift was so small that the groins were ineffective in providing a beach and the seawalls were in danger of being undermined. The South Lake Worth Inlet

6. U. S. Army, Corps of Engineers, Beach Erosion Control Study, 13 February 1947, Palm Beach, Florida; House Document #722, 80th Congress, 2nd Session.

District Commission's concern over this erosion problem and the growth of the shoaling problem in Lake Worth led to a decision to install a sand by-passing plant on the north jetty of the inlet.

The plant was installed in 1937 and consisted basically of a swinging boom attached to an 8-inch suction line, a 6-inch 65 horsepower diesel-driver centrifugal pump, and about 1,200 feet of 6 inch discharge line. It was estimated that about 60,200 cubic yards of sand were transported to the shores south of the south jetty in the first year of operation. Pronounced accretion to the area south of the inlet was immediately noticed. By 1941, beneficial nourishment was apparent for a distance of about 1 mile south of the inlet. During this period an average of about 50,000 cubic yards of sand per year was pumped. The plant was not operated from 1942 to 1945 due to fuel shortages and within this 3-year period considerable erosion took place south of the inlet. Since 1945 the pumping plant has been modified to handle a greater volume of material and recent studies[7] indicate the yearly pumping rate to be between 70,000 and 80,000 cubic yards.

The shoaling rate inside Lake Worth has been greatly reduced due to this by-passing installation, however the present magnitude of shoaling is still considered to be a maintenance problem. The downcoast area from the inlet is in excellent condition and ample shore protection is realized from the by-passing operation. The estimated annual maintenance of the by-passing plant is $10,000; this includes the salaries of two operators.

This stationary sand pumping plant as applied at South Lake Worth Inlet is one of the first installations of its type in this country. Its design and shore processes involved have received considerable interest. It is significant to point out that the estimated rate of littoral drift 16 miles north of the by-passing plant ranges from 150,000 to 225,000 cubic yards per year or perhaps 200,000 as an average. This means that the by-passing operation stabilizes the downcoast beaches by pumping only about one-third of this total volume of littoral drift. Earlier observations indicate that the by-passed material is the main source of supply to the shore immediately south of the inlet. One of the factors of success for this particular installation is that the sand reservoir at the pump's intake is a natural trap for the coarser size fraction of the littoral supply and consequently when this material is placed on the reaches to the south of the inlet it very quickly and adequately stabilizes the foreshore.

DIRECT PLACEMENT AT HARRISON COUNTY, MISSISSIPPI

As shown on the locality map, figure 5, Harrison County is situated on the Gulf Coast of Mississippi, about midway between New Orleans, Louisiana and Mobile, Alabama. The general coast line alignment of the County is east and west. This beach rehabilitation problem covers essentially the entire gulf exposed shore line of the County which is about 25 miles in length.

Transcontinental highway U. S. 90 closely borders the County's shore line. In 1915 a severe hurricane created high tides and wave action which inflicted heavy damage to this much utilized roadway. Damage to the highway plus extensive damage to beach front property led to the construction of a 25 mile-long seawall. This modern stepped-type reinforced concrete structure is reported[8] to be probably the longest continuous seawall in the world.

7. "A Study of Sand Movement at South Lake Worth Inlet, Florida," Beach Erosion Board Technical Memorandum No. 42, October 1953.
8. Beach Erosion Board Bulletin, Vol. 8, No. 3, 1 July 1954.

The seawall construction was completed in 1928 at the cost of about $3,400,000. The bottom step was at the original ground level and a low narrow beach existed at the time the seawall was constructed. Through the years wave action eroded this beach and exposed the curtain wall which supported the toe of the seawall. Difficulties were encountered, in the initial construction of this curtain wall, in making the wall sand tight; consequently, when it became exposed to direct wave action on the seaward face, there resulted extensive leaching of sand from the backfill behind the wall. This action endangered the foundation of the highway in back of the seawall, therefore the seawall was not completely effective in its primary purpose.

A Beach Erosion Control Study[9] of the Harrison County shore line was completed in 1947. The recommended plan of improvement, as set forth in this report, was to provide structural repair to the seawall with particular emphasis on a sand tight curtain wall, revision of existing drainage system, replacement of backfill and construction of an artificial beach. The plan included periodic maintenance to the seawall and replenishment of sand to the beach.

This plan was expedited in 1951. After repair of the seawall approximately six million cubic yards of sand was placed, hydraulically, directly in front of the seawall to create a beach 300 feet wide (referred to mean sea level) and about 24 miles in length. Adjacent to the wall, the beach elevation is 5 feet above mean sea level for 50 feet and thereafter sloped at 1 on 100 to the naturally adjusted foreshore slope which is about 1 on 10. The material for this beach was obtained 1,500 feet, directly offshore in Mississippi Sound.

Recent surveys indicate that this beach is in excellent shape, offering protection to the seawall and providing recreational facilities. The losses of beach material through erosion and natural adjustment of the beach has been estimated to be about 32,500 cubic yards annually. To date, no replenishment by dredging has been undertaken.

The reasons for employing the direct placement method in this beach restoration problem are apparent. The sheltering effect of the islands 12 to 15 miles offshore results in a small westerly rate of littoral drift; this sheltering effect also provides excellent conditions for floating plant operations which are reflected in the project costs. The sand deposits 1,500 feet offshore are apparently very suitable to the wave climate in the area since minimum natural foreshore adjustment has taken place.

DIRECT PLACEMENT AT SURFSIDE AND SUNSET BEACH, CALIFORNIA

Referring to figure 6, Surfside and Sunset Beaches are located on the coast of Southern California in Orange County about 4 miles southeast of the mouth of the Los Angeles River at Long Beach. Anaheim Bay Harbor lies at the westerly limit of the area. The two communities are situated on a barrier beach fronting tidal marsh land which rises slowly inland. The beaches were formed in geologic times along the face of the marsh by an abundant easterly moving littoral drift supplied by eroding headlands and debris carried to the shore by the Los Angeles and San Gabriel Rivers.

Recent erosion of these shores adjacent to the Anaheim Bay Harbor has resulted from a lack in nourishment due to a change in the local shore regimen

9. U. S. Army, Corps of Engineers, Beach Erosion Control Study, 8 March 1948; Harrison County, Mississippi; House Document #682, 80th Congress, 2nd Session.

resulting from the effects of flood control and water conservation in the tributary drainage areas, from the effects of the offshore detached breakwater extending eastward from San Pedro to a point opposite the mouth of San Gabriel River and from the effects of the converging breakwaters that protect Anaheim Bay Harbor. The rate of the littoral drift that built the beaches is not known but recent studies show that material is carried eastward from Surfside at a rate of 155,000 cubic yards per year.

Prior to 1933 private interests built a series of short groins to combat the erosion; these failed to accomplish their purpose so in 1942 a series of longer groins was built to retain the 452,000 cubic yards of artificial nourishment placed between them during the period 1942 to 1945. These groins were partially effective in holding the fill but by 1947 erosion had progressed to a point where about eight large beach homes were threatened. At this time Congress appropriated $250,000 as an emergency measure (Public Law 122, 80th Congress Approved June 27, 1947) to provide 1,220,000 cubic yards of nourishment to the beach. It was estimated that this nourishment would last approximately 5 years. During the succeeding years erosion took place, and by the summer of 1951 the shore line had receded to its 1947 predredging position at the westerly end of the beach. Since that time the erosion has moved progressively southward resulting in the loss of a number of beach homes.

A recent report[10] prepared on a comprehensive study of the area recommends the placement of artificial beach nourishment derived from Anaheim Harbor and the Marshes behind the barrier at a rate of 1 million cubic yards every 5 years. It is estimated that this quantity of material will provide protection for 6 2/3 years. The proposal to nourish the beach after 5 years is to allow a remaining protecting fillet of beach in the area adjacent to the east harbor jetty. The initial dredging will be from the harbor area which is mainly sand; subsequent dredging will be from the marsh areas which contain foreign material and consequently one million yards cannot be counted upon to last more than 5 years.

The solution of this particular problem shows the need for considering an entire littoral compartment, and when considered, the economic value of artificial nourishment to construct and rehabilitate beaches. This study is a situation where beach stabilization can be attained more economically through the use of artificial nourishment, where a supply of sand is close at hand, than through the use of a seawall. Artificial nourishment serves the added advantage of supplying material to the littoral drift to nourish the beaches downdrift while a seawall would merely transfer the erosion problem downdrift. Once seawall protection is started it has to be built progressively downdrift until the entire shore of the littoral compartment is protected.

DIRECT PLACEMENT AT EL SEGUNDO-OCEAN PARK, CALIFORNIA

Referring to figure 7, the stretch of beach between El Segundo and Ocean Park lies on the Southern California Coast at the head of Santa Monica Bay. Immediately behind the beach the coastal area is covered with wind-blown sand dunes extending several thousand feet inland, rising to elevations of 175 feet above the ocean.

The problem related to beach nourishment in this area was not entirely one

10. U. S. Army, Corps of Engineers, Beach Erosion Control Study, 30 November 1953, Anaheim Bay Harbor, California; House Document #349, 83rd Congress, 2nd Session.

of erosion but rather one of pollution. The outfall sewer of the city of Los Angeles in the Hyperion District discharged solid sewage into Santa Monica Bay and contaminated the beaches in the area. Public use of the beaches was prohibited in 1943. In order to alleviate this condition a sewage disposal plant was planned to be constructed in the sand dune area at El Segundo. The construction of this plant required the removal of 14,000,000 cubic yards of sand to reduce the elevation of the dunes from 175 feet down to a general elevation of 40 feet above the ocean. The problem of disposing of this quantity of spoil was a simple one since Los Angeles County had a master plan of shore line development[11,12] which provided for widening the beach with fill. The fill is to be developed into a park area through the provision of roads, vehicle parking areas, bathhouses, playgrounds, etc.

Conforming to the master plan the 14,000,000 cubic yards of material were pumped on the beach over the 6-mile stretch from El Segundo to Ocean Park in 1948. The beach was widened from 600 to 800 feet. Because of the character of the littoral drift in this area which moves downcoast at a rate of about 160,000 cubic yards per year, the master plan indicates that some stabilization of the shore line by artificial nourishment should be employed to retard part of the drift or replace that carried downcoast. Since man-made structures will undoubtedly appear upcoast in the future it appears that a stockpile of sand at the updrift end of each littoral segment would have to be employed. A stockpile of about 800,000 cubic yards is estimated to be sufficient for about 5 years. Sand for this fill can be procured from the foothills and dunes for a cost of about 30 to 50 cents per cubic yard.

From the time the fill was made in 1948 until the present no additional fill has been placed. Surveys[13] made to -20-foot depth in the area from 1949-1953 indicate that there has been considerable movement of the material, with losses about equal to what might be expected. From the southerly limit of the fill to Ballona Creek, a distance of about 4 1/3 miles, the loss has been in the order of one million cubic yards or about 225,000 cubic yards per year. This is in order with the 160,000 cubic yards estimated annual loss when readjustment of the artificial fill is considered, along with the supply demand in the littoral stream. Reaches on to the north (remaining 2 miles of study area) indicate stability and at points substantial accretion; the most apparent being behind the Santa Monica Breakwater. This accretion is due to the material movement from upcoast as the littoral drift moves from north to south in this area.

CONTINUOUS NOURISHMENT AT DURBAN (PORT NATAL), SOUTH AFRICA

Referring to figure 8, Durban (Port Natal) lies on the southeast coast of Africa about 800 miles northeast of the Cape of Good Hope, adjacent to Cape Natal. The city which had a population of about 367,000 in 1949 is one of the leading year round holiday resorts in South Africa. Durban like most coastal resort cities depends upon its beach to attract visitors. Erosion over the years, however, has reduced the proportions of the beach to a point where the

11. U. S. Army, Corps of Engineers, Beach Erosion Control Study, 5 June 1952, Appendix II-Coast of California, Point Mugu to San Pedro Breakwater; House Document #277, 83rd Congress, 2nd Session.
12. Civil Engineering, July 1948, Vol. 18, No. 7, Los Angeles $41,000,000 Hyperion Project, Ends Beach Contamination.
13. Los Angeles City and County Surveys (1949-1953), unpublished.

city officials feel that there is a danger of losing the lucrative tourist trade.

The erosion problem is associated with the harbor breakwaters, commenced in the 1880's, and in particular with the intensive dredging that has been necessary in the vicinity of the harbor entrance channel. This navigation channel has prevented an abundant littoral drift from reaching the Durban beaches. As a consequence over 40 acres of foreshore has been lost in about 40 years. Over the years about 60,000,000 cubic yards of material have been removed from the vicinity of the harbor entrance in maintaining a -42-foot Low Water Ordinary Spring Tide channel.

In 1938, sand derived from channel maintenance was pumped into the beach from a hydraulic dredge operating along the inside of the north jetty. The dredge has a 42-inch discharge line. In 9 years over 5,000,000 cubic yards of sand were placed on the beach. This pumping operation restored the foreshore, reclaiming about 75 acres except in the area north of West Street along lower Marine Parade where a rubble wall had been built to combat the inroads of erosion. In this area relief was only temporary.

In 1950, in order to reduce harbor maintenance dredging and also supply sand to the beach, a 16-inch dredge pump was installed on a steel trestle in Cave Rock Bight. The unit which consists of a crane and pump moves along trestle for storage at the inner end in stormy weather. During operational weather the unit works at the outer end of the trestle, dredging over a semicircular area (radius 36 feet) to a depth of -20 feet L.W.O.S.T. The discharge line of the pump when in dredging position is connected to a steel line with a rubber sleeve. The line crosses the harbor at -42 feet L.W.O.S.T. and now discharges on the beach at a point just clear of the base of the north jetty. Previously the discharge point was 5,000 feet farther north effected by two booster pumps spaced roughly 2,000 feet apart. The pump has been operated almost continuously since it was constructed. The estimated output of the plant operating 7 hours per day 5 days per week has been about 268,000 cubic yards of sand per year. Prior to the commencement of the pumping in Cave Rock Bight the L.W.O.S.T. line was 65 feet beyond the end of the trestle. In 1954, it is 135 feet shoreward thereof. Occasionally the plant is unable to operate continuously due to a lack of littoral material.

Engineers connected with the project feel certain that channel maintenance dredging has been reduced by the amount by-passed. The sand supply to the Durban shore has maintained the position of the beach except in the lower Marine Parade Area where damage has occurred during the heaviest storms.

A discharge drain acting as a groin is located about 3,600 feet north of the Parade Area. In April 1953, two groins were constructed 700 and 1,400 feet south of the discharge drain. Since that time, the low water line has been forced seaward immediately south of groin #1 a maximum of 135 feet, but subsequent storms in the fall of the year have reduced the gain to about 85 feet. Although the stormy period has reduced the quantity impounded during the fine weather, there has been a substantial gain in the width of the beach.

The engineers responsible for the construction and rehabilitation of this beach consider that the annual nourishment aided by the groins to reduce the rates of loss from the beach will rehabilitate this beach area and stabilize the entire downdrift stretch of shore after the groins are full and material starts to pass around their ends.

CONTINUOUS NOURISHMENT AT SALINA CRUZ, MEXICO

The Port of Salina Cruz[14] is located on the Pacific side of the southern part of Mexico, about 1,800 miles southeast of Los Angeles. This entire harbor has been artificially constructed. The shore line in the Salina Cruz area is oriented in essentially east-west direction and the littoral drift is in an easterly direction. The rate of littoral drift is very high, being in the order of 500,000 cubic yards annually.

The initial breakwater for protection to the harbor docks was about parallel with the general shore alignment, which would allow navigation into the harbor from the southeast. It was quickly realized that extensive shoaling existed around the easterly end of the breakwater and the direction of the breakwater was changed to nearly due south and extended towards the open ocean. Another breakwater was constructed on the eastern side of the harbor, thus forming the inner and outer harbors as shown on figure 9. The impounding area to the west of the harbor entrance was soon filled and for the past 40 years extensive maintenance dredging has been required to keep the entrance channel and harbor open to navigation.

To approach this maintenance problem the Board of Mexican Free Ports constructed what is reportedly the largest stationary dredge in the world. The fixed dredge consists of two 450 horsepower motors to operate two dredge pumps equipped with 18-inch intake and discharge lines. The location of the pumping station, discharge line, and general features are shown on figure 9. There are six swivel type intake lines which feed into the dredge pumps, and the pond or reservoir created by these intakes can be about 200 feet in length, 100 feet in width and 32 feet deep.

After initial plant construction, the seaward limit of this pond was in the order of 150 feet from the mean low water line on the beach; the plan being to breach this barrier and allow the sand to flow naturally into the pool or reservoir. Attempts to open the barrier between the pond and beach were not too successful with a conventional dragline and land equipment, as each time an opening was made, large quantities of sand would deposit in the reservoir area and the pumps could not adequately handle the volumes to maintain the opening. Eventually a reinforced concrete sheetpiling passageway was constructed and a drag scraper, operated by a winch and guided by steel cables passing over a pulley installed on a float anchored at sea, pulled the material into the reservoir. A spur dike (groin) was constructed about 1,800 feet to the west of the by-passing plant, in order to reduce the rate of littoral drift at the plant.

A great amount of revealing information has been derived from the development of this sand by-passing plant. Due to the difficulties of attaining the desired readjusted shore line, the degree of successful operation has yet to be evaluated. In July of 1952, the beach line in front of the reservoir pools had not appreciably receded. It appeared, at that time, that the sand must be artificially pulled into reach of the suction lines at considerably greater rates in order to cause the beach to recede to a point where the sand flows naturally into the pool. Final appraisal of this operation should lead to a better understanding of large scale sand by-passing plants, their effect on updrift shore lines, effect of shoaling in the navigation channel, effects to the downdrift areas, and some indications on comparative maintenance costs for navigation inlets.

14. Beach Erosion Board Bulletin, Vol. 5, No. 3, July 1951.

CONCLUDING REMARKS

It can be noted, from the cases presented herein, that there are two basic methods of artificial nourishment to beaches. These are stockpile and continuous nourishment. To state that one method is superior to the other method would not be true as it is common experience in coastal engineering to find that the application of one method in a particular locality would be most unsound to utilize in another locality. For example the distribution of material into the littoral zone from a stockpile of material depends on the hydrography and predominate wave characteristics, and it would be unwise to stockpile material on a foreshore zone when the hydrography is that of steep slopes and the predominate waves have high steepness values, (wave steepness being a ratio of the wave height to the length).

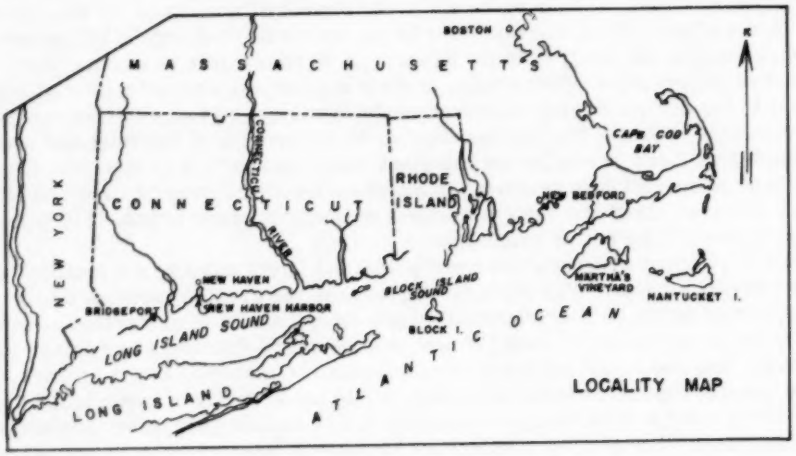
When it is considered that the technique of artificial nourishment was not extensively employed until after World War II, a realization is made of the infancy of this method of rehabilitating beaches. It was pointed out in the Atlantic City, New Jersey beach restoration approaches that the method of offshore deposition didn't appear too encouraging. Perhaps this is the case; however, conclusive criticism of this technique cannot be made until more is known about the actual mechanics of material transport by waves. After the offshore deposition, the foreshore area indicated continued erosion, but there could very easily be an effort of reduced rate of erosion due to this offshore deposition. In some coastal waters, it is known that in a matter of years a tremendous volume of material is moved in the offshore zone, however, there is still much to be understood about the actual mechanics of this material movement.

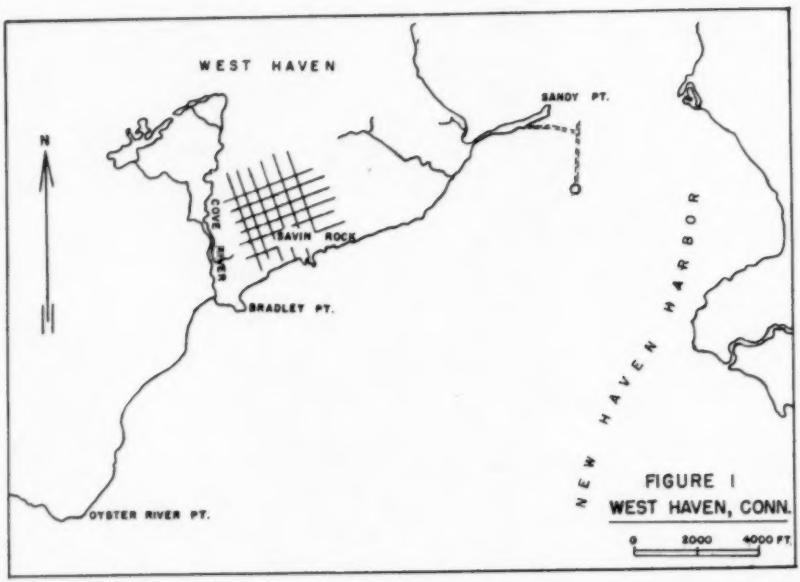
When immediate protection is needed and the fill is placed directly on the beach, there can be no actual failure of beach rehabilitation. The success of the operation can be measured by the length of time the protective beach has existed. The sand is placed directly on the foreshore, protection is provided to the onshore area and it is a question of how long will this protective beach exist. Perhaps one of the most important considerations in employing direct placement fill is the characteristic of the material being placed on the beach. A material whose gradation is fine, relative to the material environment where it is being placed, will in all probability be quickly transported to the offshore zones and the net residual of this placed material will be insufficient to provide the required beach width for protective measures. A material whose gradation is coarser than the native beach material where direct placement is desired, will be the most successful in terms of foreshore adjustment and providing the desired protective beach width over the longest span of time. It is obvious that an optimum exists for the coarseness of material in terms of a beach for recreational purposes.

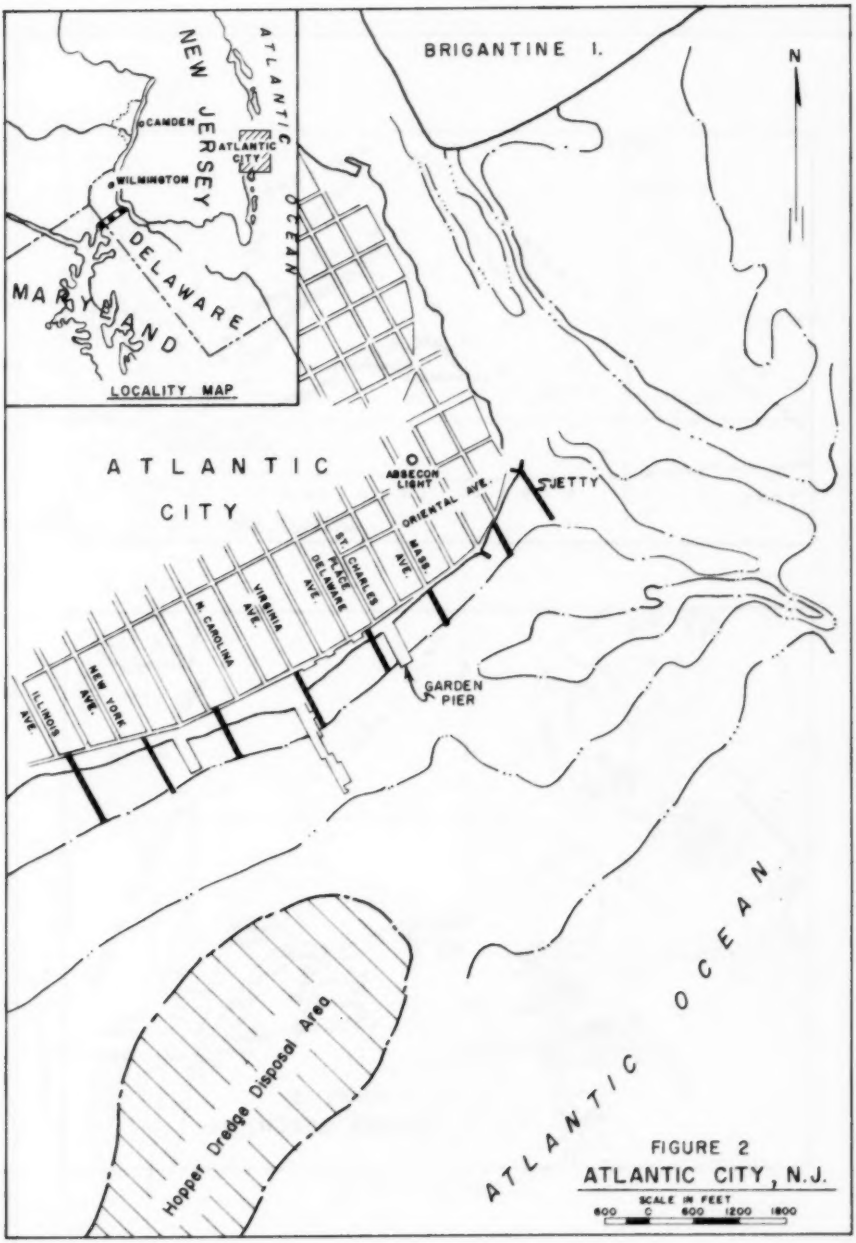
Our present experiences indicate that there is always a gradation towards finer materials as progression is made from the foreshore area towards the offshore area. In general, too, the coarsest fraction is found at the plunge point of the waves. These residuals of sand movement due to the hydraulic characteristic of the waves are all in favor of the operating of a continuous nourishment type of beach rehabilitation. Here, the plant is positioned to intercept this coarse fraction and transport it to the downdrift areas where it will function as a feeder to the Littoral Stream. When the outfall of the bypassing plant is not systematically extended, the operation becomes a form of stockpiling and this requires additional time for the natural forces to transport the material downcoast. When observations are made at the sand bypassing plant at South Lake Worth Inlet, Florida, there is a tendency to

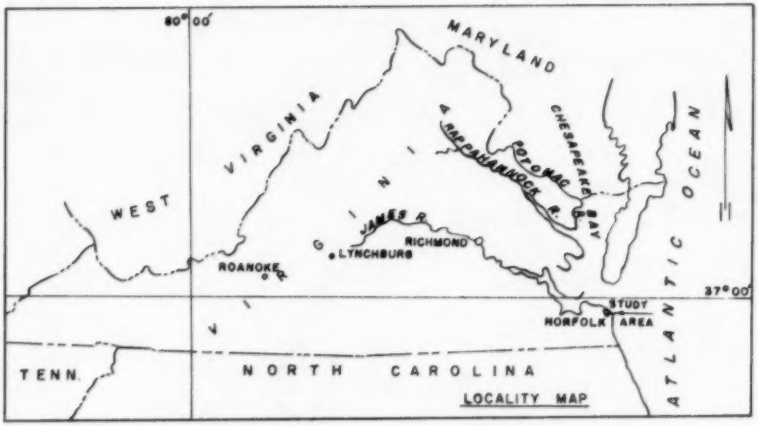
conclude that this type of artificial nourishment is the solution to all inlet problems; then when observations are made of the sand by-passing operations at Salina Cruz, Mexico it is realized that the overall planning is not so simple. Here again, this type of nourishment to the downdrift area from an inlet, and the dual purpose of the operation to reduce maintenance dredging to the navigable waters in the inlet, is in its infancy. It is reasonable to assume that this type of operation would always provide a desirable characteristic of material to the downdrift area; however evaluation must be made of this operation towards reducing the maintenance costs of dredging in the inlet and what possibilities there are of having the plant "land-locked." It is apparent that this type of operation is receiving much attention at the present time and as more is known about the basic movement of sands by wave action, this type of operation can be better evaluated.

It can be noted that little has been presented in the cited beach restoration cases towards costs. This item, of course, has the greatest bearing on the selection of artificial nourishment. In one case the cost of protecting a reach of shore line by artificial nourishment may be only a few cents per linear foot of shore line due to the accessibility of the source material and in another case the costs would be extremely high due to the scarcity of materials. In this latter case it is often more economical to consider permanent protection such as massive seawalls or bulkheads to protect valuable onshore property, and in some cases the value of the onshore property does not justify the total costs of adequate protection from the ocean waves.


BOSTON
MASSACHUSETTS
N
CAPE COD BAY
CONNECTICUT
RHODE ISLAND
NEW BEDFORD
CONNECTICUT RIVER
NEW YORK
NEW HAVEN
NEW HAVEN HARBOR
BRIDGEPORT
BLOCK ISLAND SOUND
BLOCK I.
MARTHA'S VINEYARD
NANTUCKET I.
LONG ISLAND SOUND
ATLANTIC OCEAN
LONG ISLAND
LOCALITY MAP


WEST HAVEN
SANDY PT.
N
COVE RIVER
SAVIN ROCK
BRADLEY PT.
NEW HAVEN HARBOR
OYSTER RIVER PT.
FIGURE 1
WEST HAVEN, CONN.
0
2000
4000 FT.


BRIGANTINE I.
N
NEW JERSEY
ATLANTIC OCEAN
CAMDEN
ATLANTIC CITY
WILMINGTON
DELAWARE
MARYLAND
LOCALITY MAP
ATLANTIC CITY
ABSECON LIGHT
JETTY
ORIENTAL AVE.
MASS. AVE.
ST. CHARLES PLACE
DELAWARE AVE.
VIRGINIA AVE.
N. CAROLINA AVE.
NEW YORK AVE.
ILLINOIS AVE.
GARDEN PIER
Hopper Dredge Disposal Area
ATLANTIC OCEAN
FIGURE 2
ATLANTIC CITY, N.J.
SCALE IN FEET
600 0 600 1200 1800



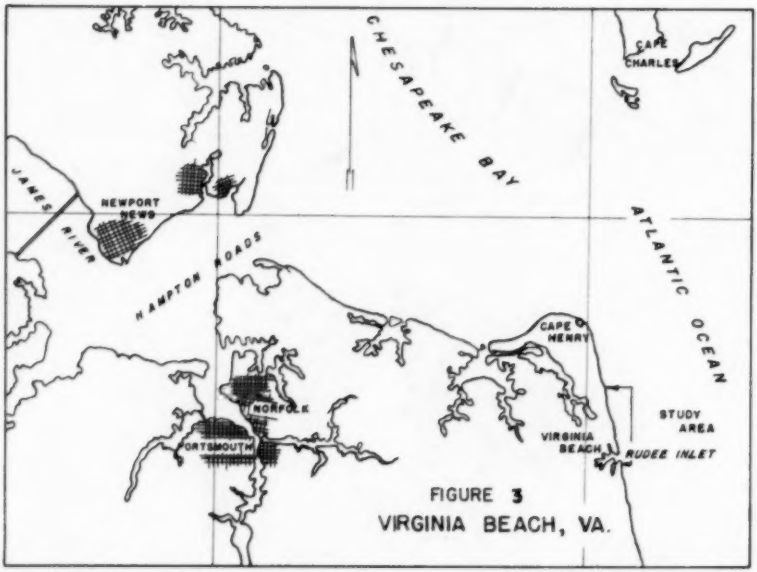


FIGURE 3
VIRGINIA BEACH, VA.

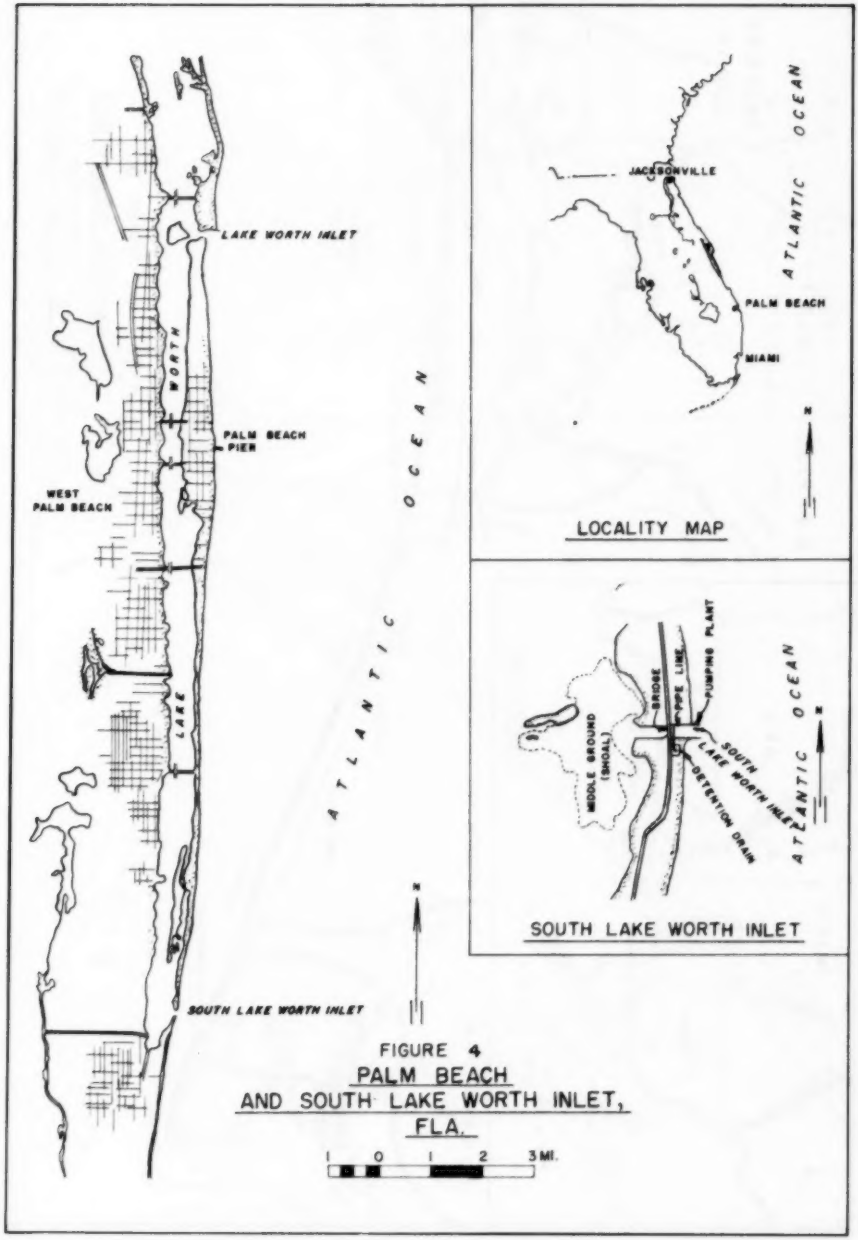


FIGURE 4
PALM BEACH
AND SOUTH LAKE WORTH INLET,
FLA.

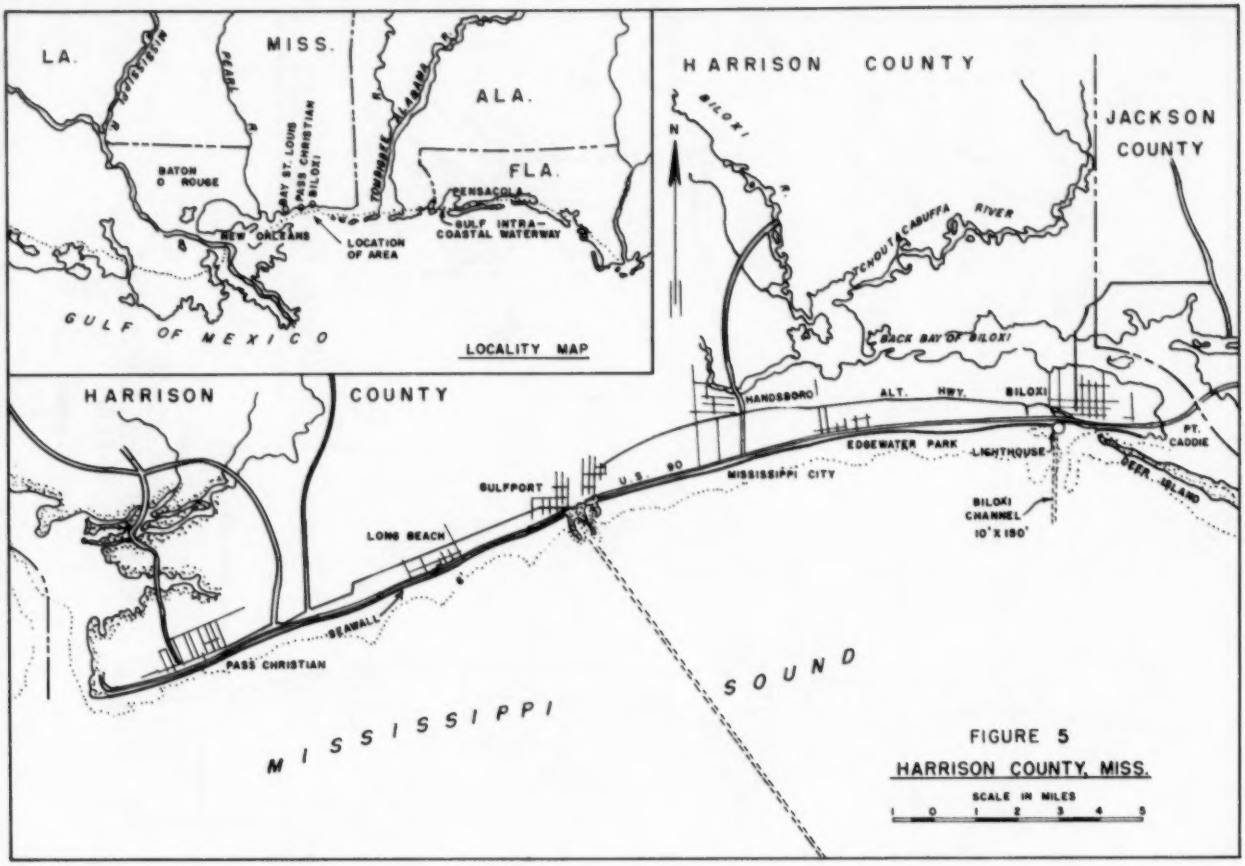


FIGURE 5

HARRISON COUNTY, MISS.

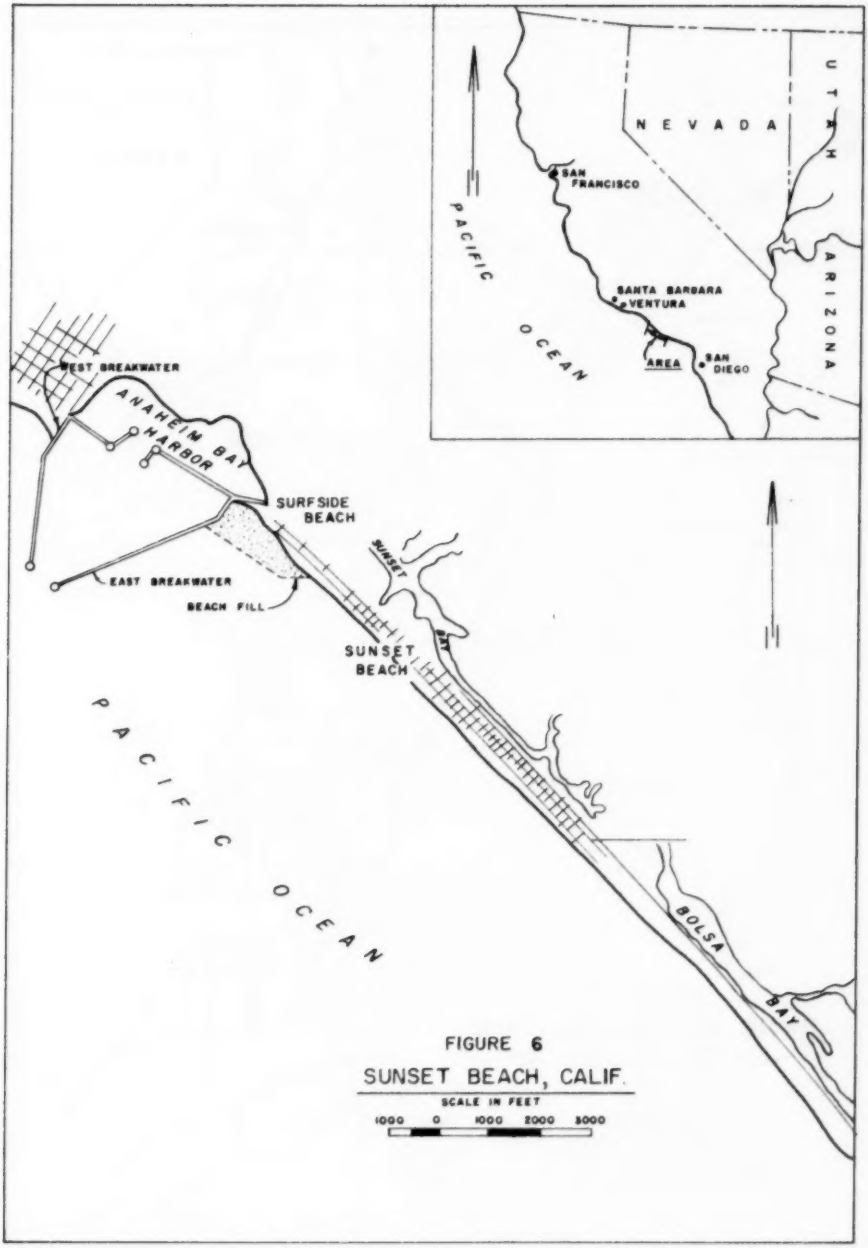


FIGURE 6

SUNSET BEACH, CALIF.

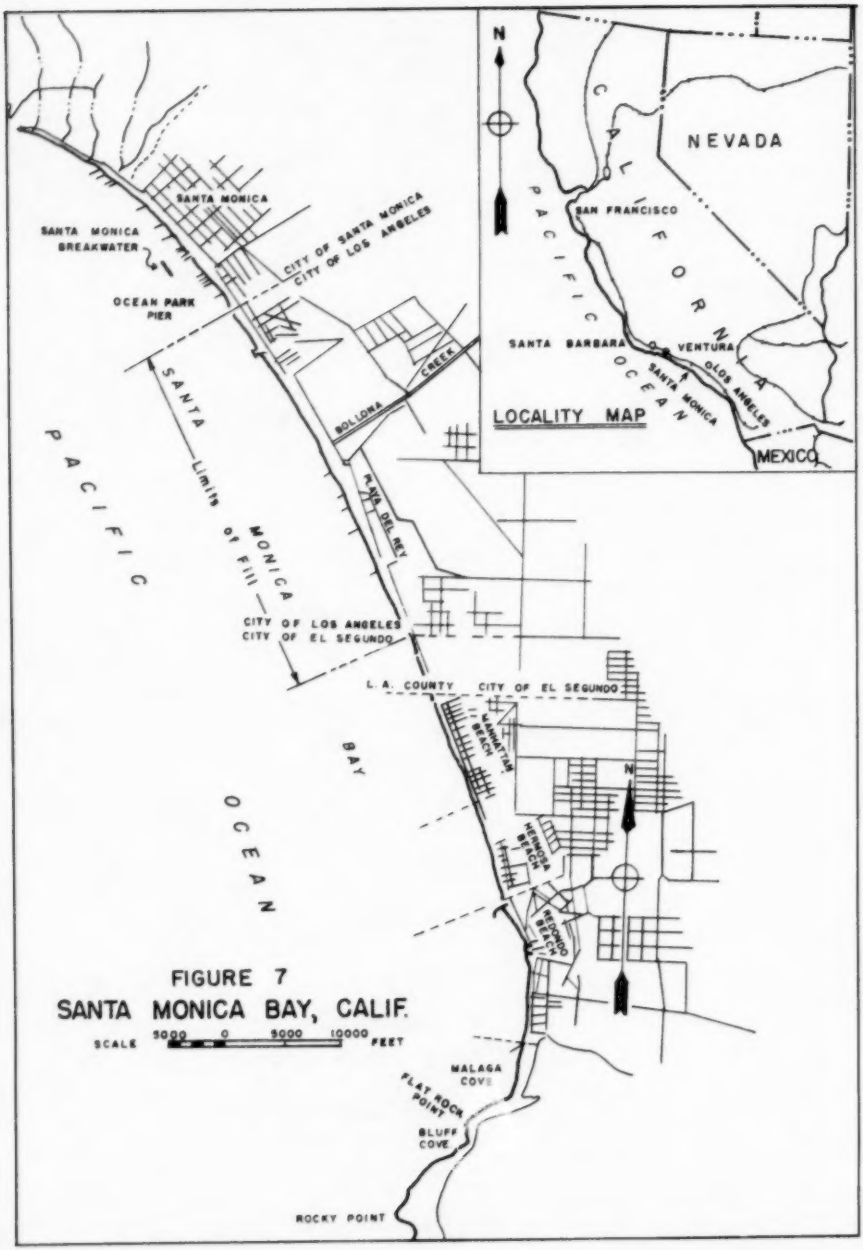


FIGURE 7
SANTA MONICA BAY, CALIF.

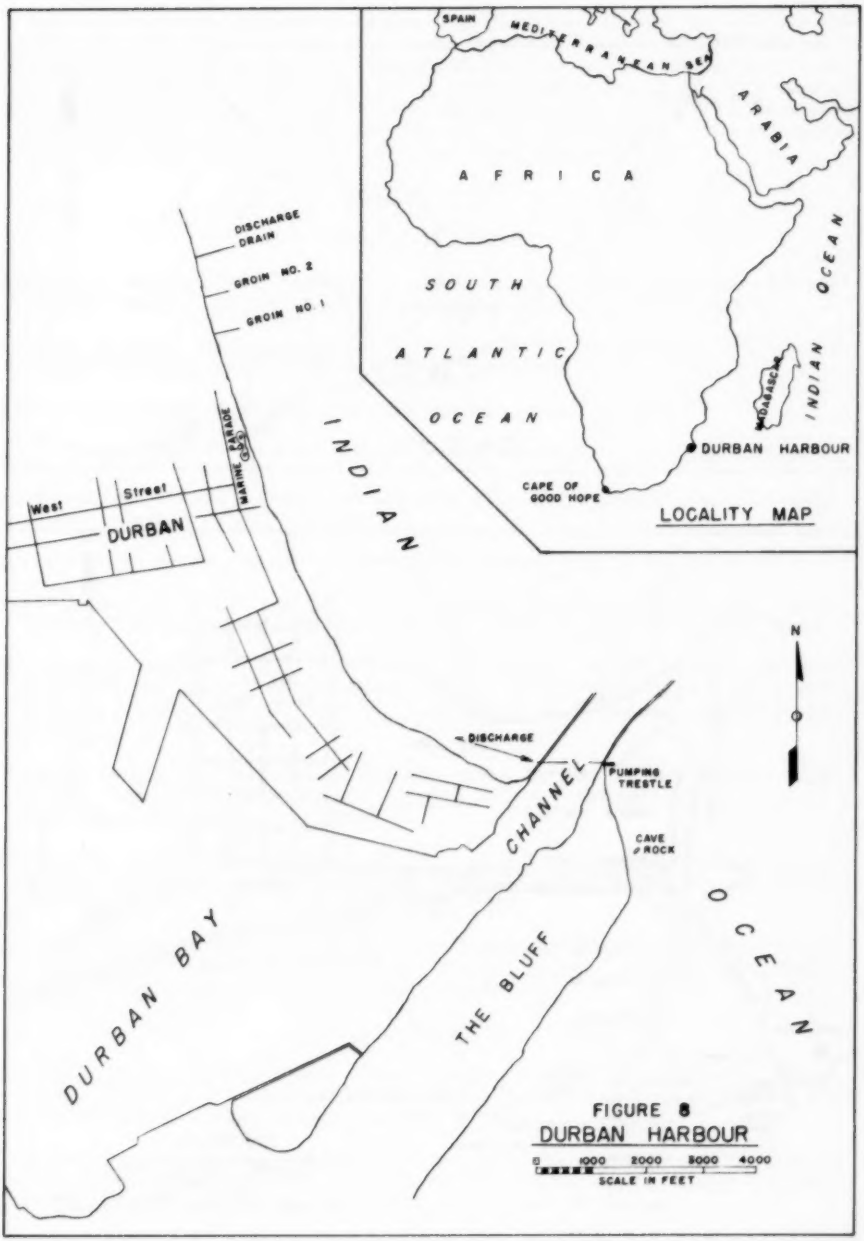


FIGURE 8
DURBAN HARBOUR

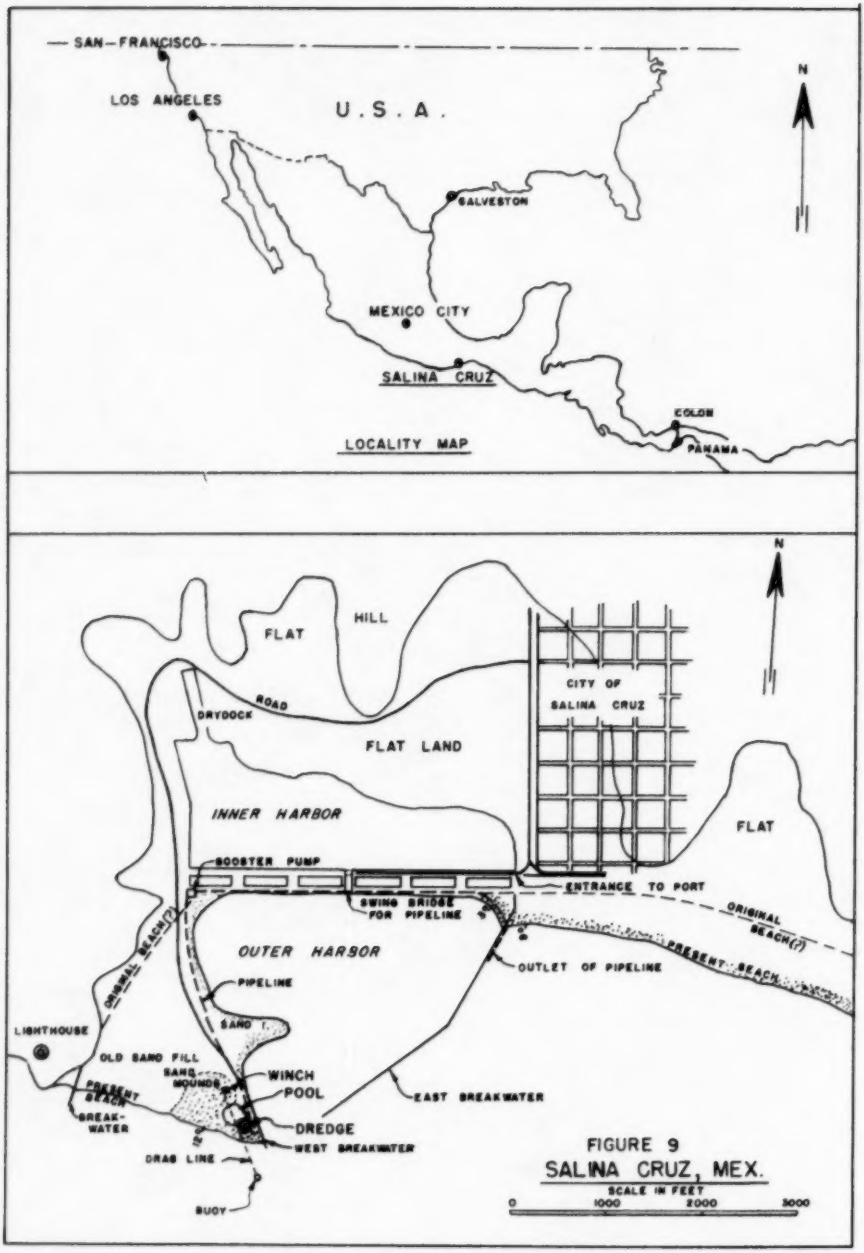


FIGURE 9
SALINA CRUZ, MEX.

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The technical papers published in the past year are presented below. Technical-division sponsorship is indicated by an abbreviation at the end of each Separate Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways (WW) divisions. For titles and order coupons, refer to the appropriate issue of "Civil Engineering" or write for a cumulative price list.

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NOVEMBER: 534(HY), 535(HY), 536(HY), 537(HY), 538(HY)[c], 539(ST), 540(ST), 541(ST), 542(ST), 543(ST), 544(ST), 545(SA), 546(SA), 547(SA), 548(SM), 549(SM), 550(SM), 551(SM), 552(SA), 553(SM)[c], 554(SA), 555(SA), 556(SA), 557(SA).

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c. Discussion of several papers, grouped by Divisions.
d. Presented at the Atlanta (Ga.) Convention of the Society in February, 1954.
e. Presented at the Atlantic City (N.J.) Convention in June, 1954.

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